2.0 TETON FAULT- SOURCE CHARACTERIZATION

2.1 Introduction

The Teton fault is one of several major late Quaternary faults within the Intermountain Seismic Belt region surrounding Jackson Lake Dam. These faults include the Centennial, Hebgen Lake, and Madison Range normal faults to the north and west of the dam, as well as the seismically active Yellowstone Caldera and the Star Valley and Greys River faults to the south near the Snake River Range (Figure 2-1). In addition to these earthquake sources, there are numerous other late Quaternary faults and potential seismic sources in the region surrounding Jackson Lake Dam (Wong et al., 2000; Machette et al., 2001). The surface trace of the Teton fault lies along the western shore of Jackson Lake, within about 12 km (7 mi) of Jackson Lake Dam and dips to the east potentially extending beneath the damsite if fault dips are less than ~ 45° (Figure 2-2). Late Quaternary fault scarps, the product of multiple Holocene surface faulting events, are present along about 60 km (37 mi) of the fault trace. Previous engineering analyses by Reclamation at Jackson Lake Dam have assumed that the Teton fault is the controlling seismic source for analyses of the dam based on proximity and maximum earthquake magnitudes, and this assumption appears to be confirmed by results from a preliminary probabilistic hazard analyses (Wong et al., 2000).

In this section the seismic source characteristics of the Teton fault are provided. The initial task in this assessment is to delineate the extent of rupture associated with past earthquakes on the Teton fault as shown by late Quaternary fault scarps and faulted Quaternary deposits. These data also provide information on the age and frequency of faulting events, and on the geometry of individual fault planes associated with paleoearthquakes on the fault. For ground motion analyses, the objective is to describe the constraints imposed by the available data on the location (coordinate information), orientation (strike and dip), and slip characteristics (slip per event) of fault planes associated with potential earthquakes on the Teton fault. For probabilistic analyses, it is necessary to describe the extent, size, ages, and frequency of paleoearthquakes along the fault, or to describe the behavior of the fault in terms of a slip rate and various models of earthquake occurrence. For both ground motion and probabilistic analyses, it is necessary to consider

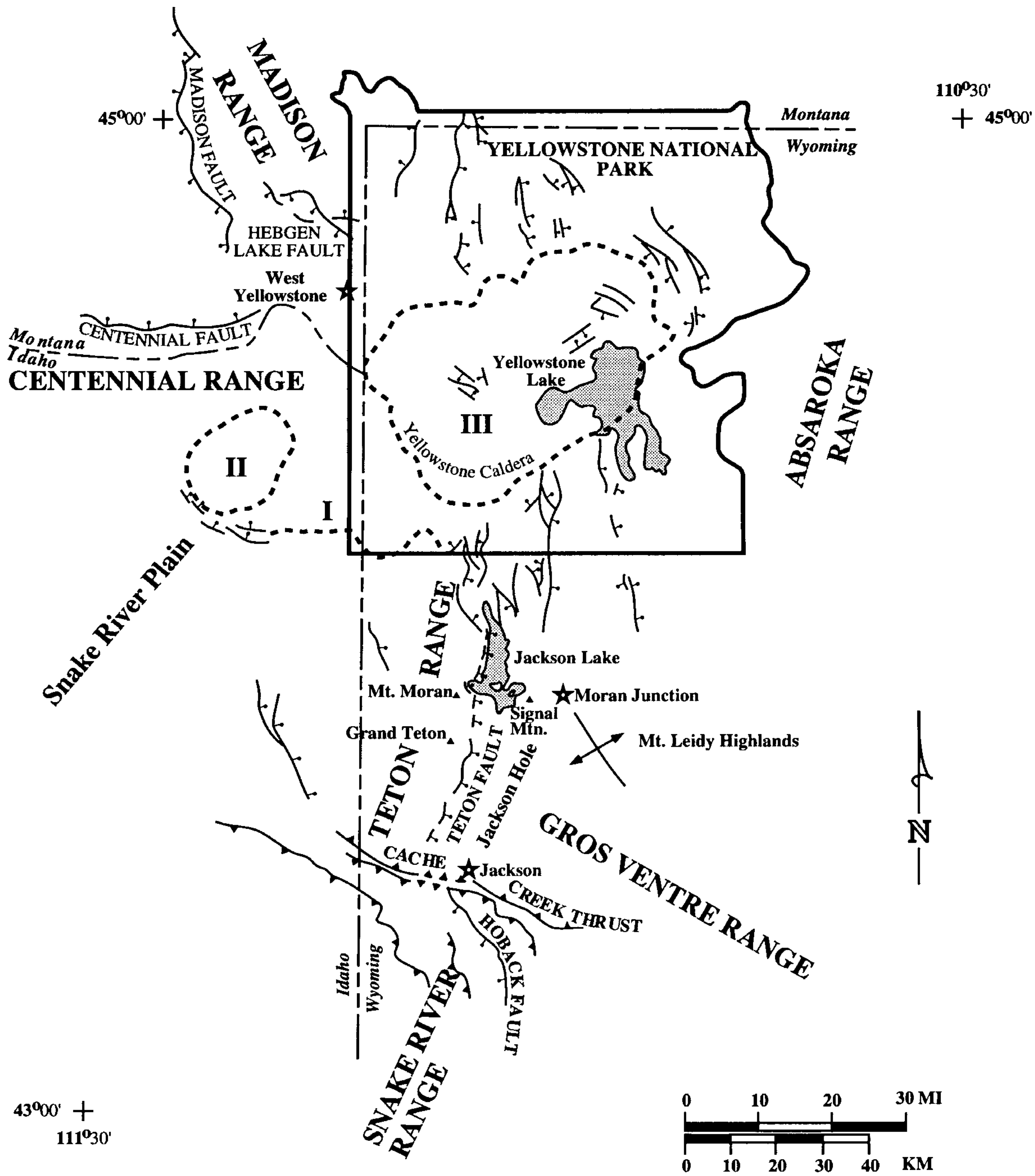

Figure 2-1: Regional tectonic map of the northwestern Wyoming and Jackson Lake Dam region. Ages of Yellowstone calderas (outlined with dashes): I = 2.0 Ma, II = 1.2 Ma, and III = 0.6 Ma. Normal faults shown with hachured symbol on downthrown side; thrust faults with barbs on overthrust block. Figure from Smith et al. (1993b).

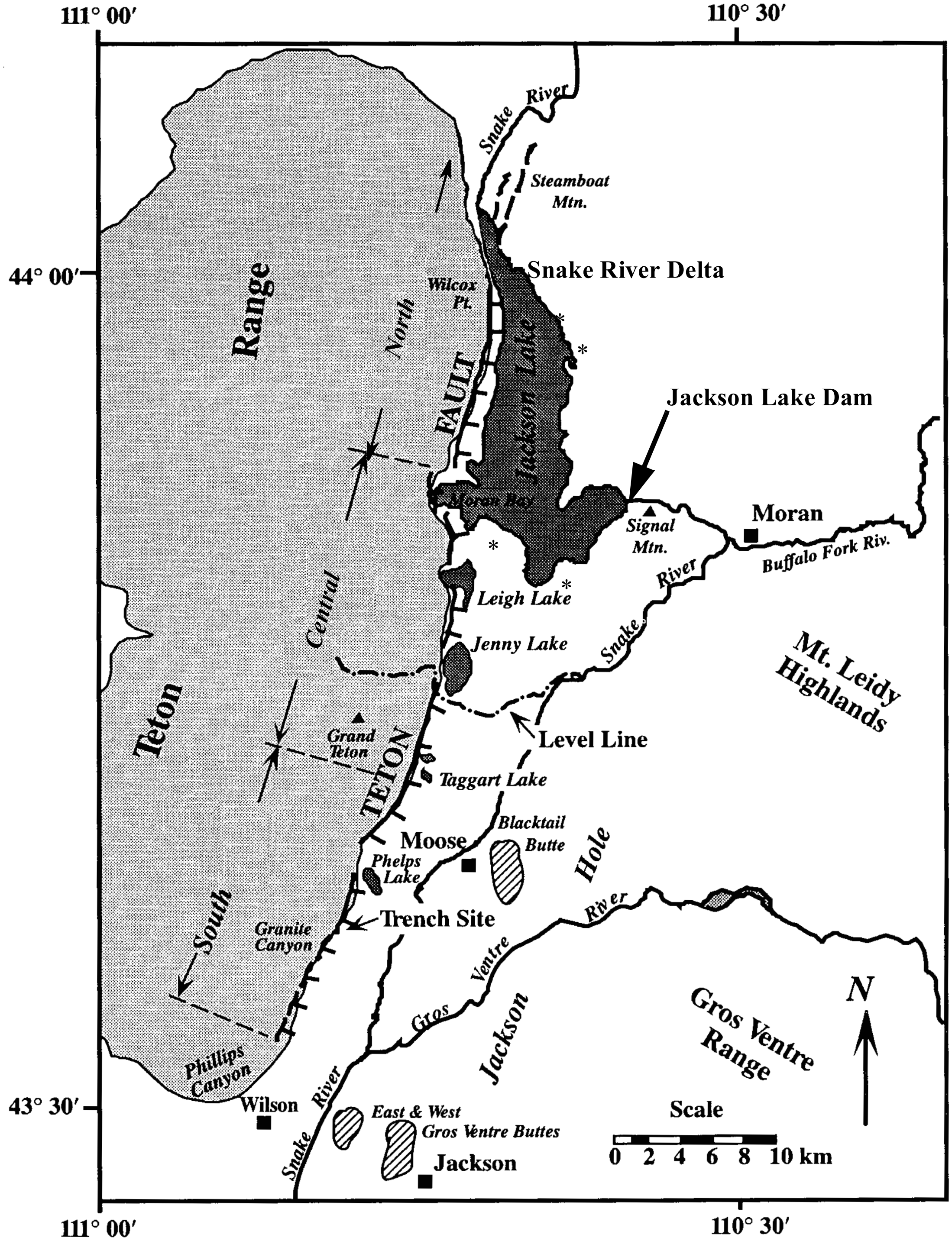

Figure 2-2: Map of the Teton Range-Jackson Hole region showing the generalized late Quaternary trace of the Teton fault in relationship to Jackson Lake Dam. Approximate boundaries of sections of the Teton fault are indicated with arrows along the fault. Approximate locations where submerged shorelines of Jackson Lake date paleoseismic events are shown with *around the margins of Jackson Lake. "Trench Site" is the Granite Creek site of Byrd et al. (1994) and Byrd (1995). Cross-hachured areas are outcrops of Paleozoic rocks in Jackson Hole. Figure slightly modified from Smith et al. (1993b).

potential alternative models of fault behavior and the uncertainties in descriptive data and fault models.

2.1.1 Primary Data Sources. There are three primary sources of data for the seismic source characterization of the Teton fault: 1) previous Reclamation seismic hazard studies, 2) research studies by the University of Utah, and 3) research and mapping projects by the U.S. Geological Survey. Although some of these studies have been quite extensive and limited areas studied in great detail, overall, the Teton fault has been mapped in only moderate detail and there is relatively little detailed information available on the paleoseismic history of the fault. Of particular importance is the lack of a detailed fault map coupled with detailed mapping and dating of the Holocene to late Pleistocene deposits in which fault scarps are found.

Several previous Reclamation seismic hazard studies have addressed the Teton fault in some detail. Seismotectonic studies for Jackson Lake Dam by Gilbert et al. (1983) summarized previous studies, produced the first map which depicted the extent of fault scarps along the Teton fault, and developed slip-rate estimates based on the estimated offsets of the 2-Ma old Huckleberry Ridge tuff and late Quaternary deposits along the range front. As part of a seismotectonic study for Grassy Lake Dam, Ostenaa et al. (1993) mapped fault scarps along the northern section of the Teton fault in greater detail and evaluated evidence for fault activity along several potential traces of the Teton fault north of Jackson Lake. Based on data from these studies, Ostenaa and Gilbert (1988) described some potential geometric controls on the segmentation of the Teton fault. Most recently, Wong et al. (2000) compiled fault activity and slip rate data for many faults in the region as part of a preliminary probabilistic hazard evaluation for Jackson Lake Dam and several other Reclamation dams in the region.

Research by the University of Utah since the 1980's has resulted in several significant contributions to understanding the paleoseismic history of the Teton fault. Field investigations extended the mapping and provided additional offset measurements of late Quaternary fault scarps (Susong et al., 1987; Byrd, 1995). Geophysical investigations in Jackson Lake identified potential fault traces in the lake sediments (Smith et al., 1993a). At one site, Granite Creek, trench investigations provided detail on the Holocene displacement history of the fault (Byrd et al., 1994). A level line across Jackson Hole has provided a basis for repeated measurements of deformation in the basin. Results of these field investigations, including models of fault behavior and segmentation, and analyses of leveling results are presented in several publications (Byrd et al., 1994; Smith et al., 1993b; Sylvester et al., 1991).

Mapping by J.D. Love of the U.S Geological Survey provided the earliest descriptions of the magnitude and recency of faulting on the Teton fault (e.g., Love and Montagne, 1956; Love and Reed, 1971; Leopold and Love, 2002). Compilation geologic maps of the Grand Teton National Park (Love et al., 1992) and the State of Wyoming (Love and Christiansen, 1985) provide a framework for the overall structure and geologic setting of the fault. Ongoing studies of the Quaternary glacial history of the Yellowstone - Teton region provide much of the chronologic data for evaluating the age of fault scarps and resulting estimates of slip rates (Pierce and Good, 1992). Detailed geoarcheology studies of sites submerged by Jackson Lake Reservoir yielded evidence of the ages and amount of offset for multiple Holocene earthquakes on northern and central sections the Teton fault (Pierce and Good, 1992; Connor, 1998). Results of previous studies for the Teton fault and other faults in the region have been compiled in a database which provides slip rate and other fault characterization data (Machette et al., 2001).

2.2 Late Quaternary Faulting on the Teton Fault

2.2.1 Quaternary Chronology of Faulted Deposits Along the Teton Fault. The Quaternary chronology of faulted deposits, together with the amounts of faulting, is the data from which estimates of faulting rates are derived. To the extent that there are large gaps in the detailed understanding of the ages of deposits along the fault, there will also exist significant uncertainty in the rates and chronology of faulting and earthquake recurrence. While there is a broad understanding of the geomorphic history and ages of the faulted Quaternary deposits along the front of the Teton Range (e.g., Love et al., 1992), there has been relatively little detailed mapping and chronology developed for most sites where fault scarps have been mapped. In general, four broad groups of late Quaternary (past 140 ka) deposits are clearly faulted: 1) glacial deposits in Jackson Hole related to ice lobes which primarily sourced from the highland areas of the Yellowstone Park area to the north and northeast, 2) glacial deposits related to local glaciers flowing out of the Teton Range, 3) deposits along glaciated drainages that post-date the major deglaciation of the Teton Range glaciers and Yellowstone ice sheet, and 4) colluvial deposits that blanket the slopes of the Teton Range front between major drainages. Each of these four groups includes several different types of deposits and can potentially include deposits with ages that span as much as 20,000 to 40,000 years.

The first broad group of deposits includes extensive deposits associated with oldest well-documented glaciation in Jackson Hole, termed the Munger (Bull Lake? or glaciation 2 of Love et al., 1992), as well as deposits of younger, Pinedale glaciers that entered Jackson Hole. The volume of ice flowing into Jackson Hole at the peak of the Munger glaciation was of such extent that all of Jackson Hole was filled with ice (e.g., Love and Reed, 1971; Love et al., 1992; Pierce and Good, 1992). Based on correlation to dated glacial deposits at West Yellowstone and to the marine oxygen-isotope stage record, the age of this glaciation is thought to be about 130,000 - 170,000 ka (Pierce and Good, 1992). Although no fault scarps are mapped in deposits of the Munger glaciation along the Teton fault, at Timbered Island and Windy Point, these deposits are apparently tilted towards the fault, indicative of significant cumulative displacement.

The last and most recent large-scale glaciation in Jackson Hole, the Pinedale, consisted of at least two phases (Pierce and Good, 1992; Connor, 1998). During both phases of the Pinedale glaciation, ice lobes flowed into Jackson Hole from highland areas to the north and northeast and built large end moraines and outwash surfaces in Jackson Hole south of Jackson Lake. Related moraines and recessional deposits are present on both the west and east shores of Jackson Lake. Along the west shore of Jackson Lake, some of these deposits straddle the trace of the Teton fault (Love et al., 1992; Pierce and Good, 1992; Ostenaa et al., 1993). Glaciers from the Teton Range apparently extended only a relatively short distance out from the range front and made relatively small contributions to the ice lobes in the main valley. However, the detailed history of individual sequences derived from the range-front glaciers and the deposits of the main valley ice lobes has not yet been described. Moraines constructed by Pinedale-age range-front glaciers also cross the Teton fault in several areas and are clearly faulted (Gilbert et al., 1983; Love et al., 1992).

The older phase of the Pinedale glaciation in Jackson Hole is termed the Burned Ridge. There are no direct ages in Jackson Hole on deposits of this phase and the age of the Burned Ridge is estimated by correlation to the marine oxygen-isotope stage record. This correlation suggests an age range of about 35,000 to 72,000 years ago (Pierce and Good, 1992; Connor, 1998). No Teton fault scarps occur directly on the Burned Ridge deposits of the major ice lobe in Jackson Hole, but these deposits have been tilted westward by displacement on the fault (e.g., Love and Montagne, 1956; Byrd, 1995). The full extent of Burned Ridge phase deposits from range-front glaciers is unclear. It is possible that some of the older range-front glacial deposits on which fault scarps are present are in fact correlative to the Burned Ridge phase. However, no detailed mapping has been done to substantiate or refute this.

The younger phase of the Pinedale glaciation in Jackson Hole had two positions defined by deposits of the ice lobes: a maximum advance (Hedrick Pond) and a recessional stand (Jackson Lake) (Pierce and Good, 1992; Good and Pierce, 1997; Connor, 1998). Radiocarbon ages on materials recovered from drill holes at Jackson Lake and ages on samples from the Yellowstone Lake area (source area for the ice lobes) indicate the ice lobes had retreated from the Jackson Lake area by about 15,000 ^{14}C yr B.P., an age roughly equivalent to 17,000 to 18,000 calendar years (Pierce and Good, 1992; Good and Pierce, 1997; Connor, 1998). Thus, the ages of the moraines associated with the Jackson Lake recession and Hedrick Pond maximum advance are older, possibly in the range of 20,000 to 35,000 years ago.

The second broad group of deposits that are significant to evaluating the paleoseismic history of the Teton fault are the glacial deposits from glaciers flowing out of the Teton Range. Ages for these deposits along the Teton fault are inferred based on correlation to the Jackson Lake and Hedrick Pond deposits. Deglaciation of Teton Range glaciers is generally inferred to be broadly synchronous with deglaciation of the Yellowstone ice sheet, but there are no published studies that confirm this. In the Moran Bay area and other sites on the west side of Jackson Lake, glaciers from the Teton Range appear to have merged with the ice lobes that sourced in the Yellowstone area to the north and northeast. The absence of significant end moraines from the range-front glaciers in these areas appears to suggest that deglaciation of the Teton Range was mostly in phase with, or possibly slightly preceded, retreat of the ice lobes that sourced in the Yellowstone area. At many sites along the range front, there is clearly a sequence of glacial deposits, which may or may not reflect significant age differences, but detailed mapping and descriptions of these sites are generally lacking. Thus, the age of range-front glacial deposits faulted along the Teton fault is assumed to be similar to ages inferred for the Jackson Lake and Hedrick Pond deposits, or about 20,000 to 35,000 years ago. The Teton Range is assumed to have been essentially deglaciated by about 17,000 to 18,000 years ago.

The third broad group of deposits are inset within the glacial deposits that flank most drainages of the Teton Range. These deposits are related to the deglaciation and post-Pinedale processes in these drainages, and spans a time interval that appears to include several large faulting events on the Teton fault. In the steeper drainages this includes debris flows and avalanche deposits that may be related to the smaller scale post-Pinedale glaciers that were limited to the higher elevations in these drainages. In other areas, there are alluvial fan and fluvial deposits. With two exceptions, detailed chronologies for these deposits have not been developed for sites along the Teton fault. In the Jackson Lake area, Pierce and Good (1992) and Connor (1998) developed a detailed post-glacial geomorphic framework for several archaeological sites. The chronology for this framework is supported by several radiocarbon ages and archaeological dating of sites as old as about 8000 years. In the Granite Creek area, radiocarbon ages from a trench excavated across a fault scarp indicate that some of the post-glacial deposits along Granite Creek are in the range of 4000 to 8000 years (Byrd et al., 1994; Byrd, 1995). However, in other areas, portions of these deposits could be as old as 17,000 - 18,000 years, the estimated time of major deglaciation in Jackson Hole.

The fourth broad group consists of large areas of undifferentiated fan and colluvial deposits that exist between the major drainages along the Teton range front (e.g., Love et al., 1992). In some areas, fault scarps are present on these deposits, but in other areas these deposits appear to post-date the most recent surface faulting. No specific studies have been done to define a chronology for these deposits. Limited areas within these deposits are likely historic, while other areas possibly are synchronous in age with the glacial sequences discussed above. A tentative age range from 0 - 17,000 years is assigned to these sites.

2.2.2 Distribution of Late Quaternary Fault Scarps and Surface Rupture. Late Quaternary fault scarps are recognized along approximately 60 km (38 mi) of the Teton fault (Gilbert et al., 1983; Ostenaa et al., 1993; Smith et al., 1993b; Byrd et al., 1994; Byrd, 1995; Machete et al., 2001). These scarps can be followed nearly continuously along the steep front of the Teton Range from near Phillips Canyon, at the southern end of the fault, to the east side of

Steamboat Mountain, located at the north end of Jackson Lake (Figure 2-2). Gaps in the mapped continuity of the scarps are mostly associated with areas of active drainages and lakes. A notable exception is western Moran Bay of Jackson Lake, where there is an approximately 2-km stepover in the scarps, and no evidence of faulting in the glacial or post-glacial sediments beneath Moran Bay (Smith et al., 1993a).

Quaternary displacement on the Teton fault has clearly extended beyond the limits of the fault scarps mapped along the range front, as shown by the range front and structural relief at the southern end of the range (e.g., Love and Reed, 1971; Lageson, 1987) and by numerous fault traces and offset of 2 Ma year old Huckleberry Ridge tuff at the northern end of the fault (e.g., Love et al., 1992). However, existing studies have not identified evidence of surface rupture on these faults at the northern and southern ends of the range in the past approximately 15 ka (e.g., Ostenaa et al., 1993; Gilbert et al., 1983).

In previous studies, the scarps along the Teton fault were compiled on 1:62,500 scale base maps (Gilbert et al., 1983; Sussong et al., 1987; Smith et al., 1993b; Love et al., 1992), with the exception of the northern section of the fault, which was compiled on a 1:24,000 scale base map (Ostenaa et al., 1993). While the locations of many fault scarps along the Teton Range have been noted, the mapping in most areas has not been of sufficient detail to also identify a narrow range of ages for the deposits faulted at each site along the fault. Thus, for purposes of slip rate estimation and fault characterization, the offsets measured on these scarps are combined with broad age ranges based on regional correlations.

For purposes of ground motion modeling and seismic hazard calculations, the existing mapping of the fault scarps has been used as a basis to develop representations of the fault that can be used in these models. In these models, faults are depicted as planar structures, defined by a surface trace with a strike and dip, and by the depth of seismogenic fault rupture. The surface trace and strike are well defined by the distribution of fault scarps along the Teton fault. The dip of the fault is only poorly constrained by surface geology, limited subsurface data and structural models, and observational information from historical earthquakes. The depth of seismogenic fault rupture is defined by earthquake data from local and regional seismic networks, geophysical data and models, and historical earthquakes.

A somewhat simplified characterization of the surface fault geometry (Figure 2-3) is presented here for use in different ground motion and seismic hazard models. This characterization consists of 29 fault traces with varied strike and geometrical relations. Fault traces are defined based on changes in strike or discontinuities in the fault scarps. In this characterization (Appendix A, Table A-1), individual fault traces range in length from < 1 km to about 5 km and the location of each fault trace is generally within about 0.1 km of actual trace of the fault scarps.

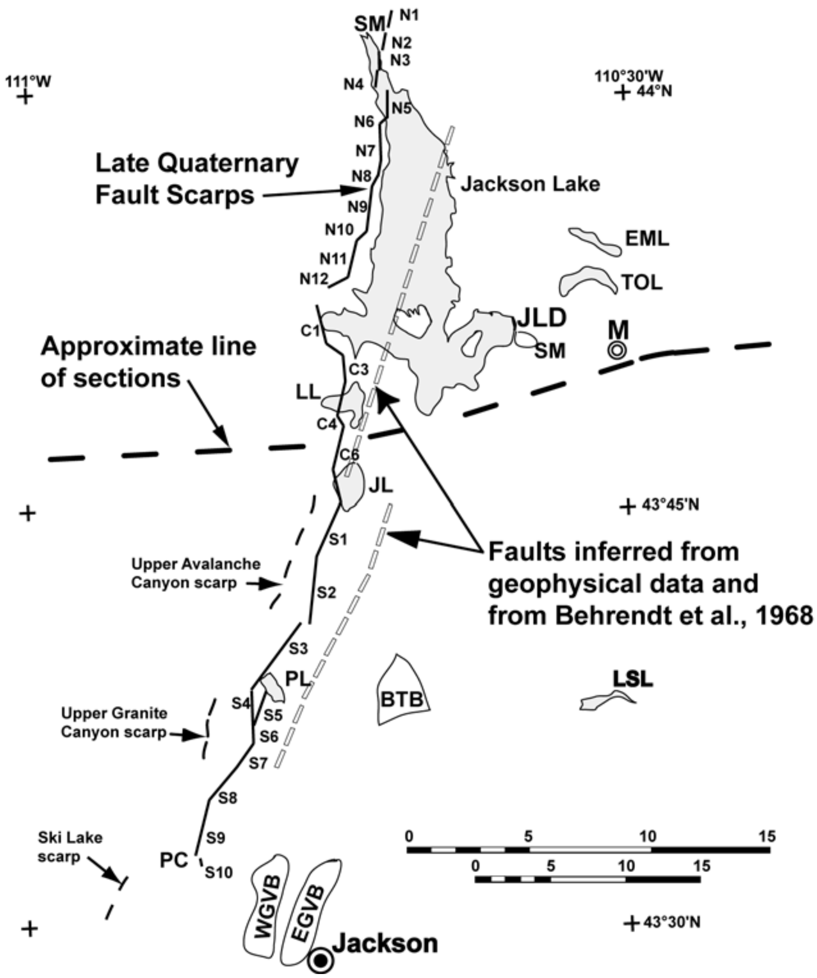

Figure 2-3: Map of fault traces defined by late Quaternary fault scarps along the Teton fault. Scarp and slip rate data for each trace are tabulated in Appendix A, Table A-2. Letter number combinations, N1, N2, etc., designate different fault traces in Appendix A, Table A-1. Dashed traces west of fault scarps are high-angle, 60-80°, faults mapped within Teton Range (Love et al., 1992) that coincide with scarps in Avalanche and Granite Canyons (Gilbert et al., 1983). Open box dashed fault traces east of fault scarps are approximate locations of buried, 35°-dipping faults defined by geophysical data (Behrendt et al., 1968). Sections across basin are shown in Figure 2-4,-5 and -6. SM- Steamboat Mountain, EML-Emma Matilda Lake, TOL-Two Ocean Lake, JLD-Jackson Lake Dam, M-Moran, LL-Leigh Lake, JL-Jenny Lake, PL-Phelps Lake, BTB-Blacktail Butte, LSL-Lower Slide Lake, PC-Phillips Canyon WGVB-West Gros Ventre Butte, EGVB-East Gros Ventre Butte.

For discussion purposes, it is convenient to consider the Teton fault as consisting of three major sections, termed northern, central, and southern (Figure 2-2). Names used for the fault sections in this report are generally consistent with Smith et al. (1993), Byrd et al. (1994) and Byrd (1995), but differ slightly from terminology used by Machete et al. (2001). However, it is not clear from the existing data on the fault whether or not these fault sections behave independently as separate fault rupture segments and earthquake sources or whether the entire fault ruptures in single earthquake events (e.g., Ostenaa and Gilbert, 1988; Smith et al., 1993b; Byrd et al., 1994; Machette et al., 2001).

The northern section of the fault (traces N1 - N12) consists predominantly of longer fault traces that strike between N-S and N10°E that alternate with short fault traces that strike about N30-65°E. In most cases, these shorter traces act as right steps to the overall trace of the fault, although a significant left step must be present beneath the northern end of Jackson Lake. Mapped fault scarps make sharp bends at these steps (Ostenaa et al., 1993). At Moran Bay, there is a substantial discontinuity in the scarps. The fault trace as defined by scarps both north and south of Moran Bay bends sharply around the bay, but does not join and there is an approximately 2-km gap in the scarps in this area. Further, geophysical surveys that cross potential projections of the fault in Moran Bay show no evidence of faulting in the sediments beneath the bay (Smith et al., 1993a).

The central section of the fault (traces C1 - C7) displays a more regular sawtooth pattern, defined by somewhat longer traces that strike about N10°E, which alternate with traces only slightly shorter that strike NW. The overall effect of the NW-striking traces is a left-stepping arrangement along this section of the fault. Throughout this central section, existing mapping indicates that the fault scarps have a high degree of continuity. In map view, the scarps have large bends and reentrants that are unrelated to steep topography which they traverse, indicating that individual fault traces have significantly disparate strikes. South of Jenny Lake the overall strike of the Teton fault becomes more northeasterly than on the central or northern sections of the fault north of Jenny Lake and the overall strike of the fault traces between Jenny and Taggart Lakes (traces C8-C9) is somewhat transitional between the fault traces north of Jenny Lake and those south of Taggart Lake. The fault trace geometry in this area is also somewhat transitional as well, but the continuity of the surface fault scarps on fault traces C8 to C9, which extend south of Taggart Lake, is very high and similar to those on the central and northern sections of the fault.

The Taggart Lake area has been generally considered as the northern end of the southern fault section (e.g., Smith et al., 1993; Byrd et al., 1994; Machete et al., 2001) Fault scarps along this section of the fault define two arcuate to wedge-shaped traces, a northern group which is set back slightly and centered on Phelps Lake (traces S1-S4), and a southern, more curved wedge in the Teton Village to Phillips Canyon area (traces S5-S7). South of Taggart Lake, overall, the fault scarps appear to be more discontinuous than along other sections of the fault, particularly in the areas near Phelps Lake and the Jackson Hole Ski area. While there are several prominent fault scarps in these areas, such as near Teton Village, Granite Creek, and north of Phelps Lake, there are also several discontinuities or gaps in the scarps. Whether these discontinuities reflect incomplete surface rupture along this section of the fault or destruction of the fault scarps by erosion and deposition is unclear based on the existing mapping. The only site on the Teton fault where fault scarps have been trenched is at Granite Creek, along trace S4 (Byrd et al. (1994); Byrd (1995).

South of Jenny Lake is the only area along the fault where mapping has shown clear evidence of left-lateral offsets along the fault (Smith et al., 1993b; Byrd, 1995). Ostenaa and Gilbert (1988) suggested that left-lateral offsets along the more northeasterly striking sections of the fault were consistent with nearly E-W oriented extension affecting the fault as a whole, and not necessarily indicative of fault segmentation. Also, along the southern section of the fault, there appears to be some evidence for late Quaternary displacement along discontinuous, subparallel, high-angle faults within the range as shown by apparent short, fault scarps that coincide with the traces of these faults in Avalanche and Granite Canyons (Gilbert et al., 1983) and southwest of Phillips Canyon near Ski Lake (Love et al., 1992; Machete et al., 2001).

Because of the overall irregularity of the fault trace, we have used simplified representations of the Teton fault geometry in ground motion models described in subsequent sections of this report. For 2 or 3 plane representations of the fault, the planar fault sections used in the models are typically within about 1 km of the surface trace defined by the fault scarps, but locally may be as much as about 2 km from the surface trace defined by the fault scarps in areas where there are large re-entrants in the scarps such as near Moran Bay. Characterization of the Teton fault as a single planar fault over the entire length of the fault scarps, inevitably leads to discrepancies of 5 km or more between the surface location of the single planar fault and the surface trace defined by the fault scarps. This discrepancy arises because overall average strike of the southern portion of the fault differs by more than 20º from the overall average strike of the central and northern portions of the fault (e.g., Figure 2-2 or 2-3). Thus, in ground motion modeling discussed in the following section of this report, the fault is displayed as two simplified planes, or simplified rupture segments. The northern rupture segment as used in the ground motion modeling consists of the northern and central fault sections discussed above, extending from the east side of Steamboat Mountain to just south of Taggart Lake (Figure 2-2 or 2-3). The southern rupture segment coincides with the southern fault section and extends from just south of Taggart Lake to Phillips Canyon.

2.2.2.1 Relationship of the Late Quaternary Fault to Older Structures. Most previous investigations of the Teton fault have recognized some linkage between the late Cenozoic deformation and earlier tectonic events in the area (e.g., Love and Reed, 1968, Lageson, 1992; Smith et al., 1993; Byrd et al., 1994). This has led to several differing views on the structure of the Teton fault. It appears that the strongest case for direct linkage between the Teton fault and preexisting structure can be made on the southern section of the fault where it appears that the fault has responded to the north-dipping Cache Creek thrust (e.g., Lageson, 1991). However, further north along the fault, the influence of this structure is diminished by its increased depth. As discussed subsequently in Section 4, geophysical characteristics of the basin differ substantially between the northern and southern portions of the basin. Some differences in perceptions of the structure of the Teton fault are the result of portraying the structure at different locations along the fault. Notably, sections based on Behrendt et al. (1968) which are drawn through the area between Jenny Lake and Jackson Lake, reflect a substantially differing structural setting from that present on the southern Teton fault nearer the Cache Creek thrust as discussed by Lageson (1992). Significant differences exist in previously published sections regarding the width and number of traces associated with the Teton fault, and the dip of fault planes considered to be part of the Teton fault (see Figures 2-4 and 2-5).

For this study, the late Quaternary trace of the Teton fault is defined by the fault scarps on Quaternary deposits along the range front. These data provide the surface location of the fault trace associated with the most recent cycle(s) of earthquake activity. In contrast, the Teton fault(s) defined by geophysical data (e.g., Behrendt et al., 1968) reflect subsurface characteristics of bedrock units and structure that may or may not be associated with recent earthquake activity. The geophysical data allow development of structural models which portray the cumulative effects of the entire history of movement on the Teton fault and other structures. The faults defined by geophysical data such as Behrendt et al. (1968), and data discussed subsequently in Section 4, define elements of the basin structure through which seismic energy radiates to reach the site of interest (Jackson Lake Dam). Thus, for the present investigation, it is important to distinguish the elements of structural interpretation which are significant to the seismogenic fault rupture from those which are significant to the overall composite structure of the basin. From this perspective, it appears that the late Quaternary trace of the Teton fault, on which the most recent series of earthquake-related surface ruptures have occurred, is not the trace which bounds the major basin that underlies northern Jackson Hole and contains a thick sequence of lower velocity, lower

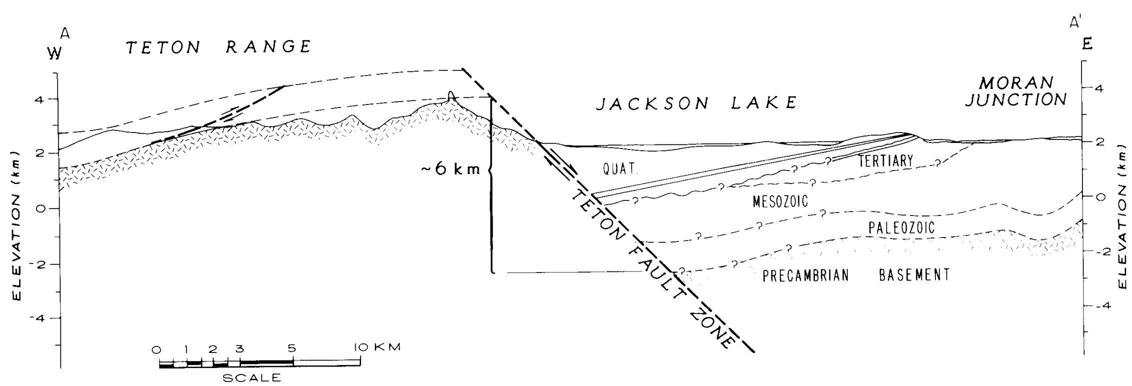

Figure 2-4: Schematic geologic cross section of the Teton Range and Jackson Hole depicting a vertical offset of ~6 km on the Teton fault copied from Smith et al. (1993). The vertical displacement is estimated based on the offset of the Cambrian Flathead Sandstone exposed on top of Mt. Moran to its projected depth beneath Jackson Hole. The subsurface configuration of Mesozoic and Paleozoic sediments beneath Jackson Hole is based on a projection of limited outcrop data and well data taken from Love et al. (1992), Behrendt et al. (1968), and Tibbetts et al. (1969). Section is vertically exaggerated. Fault dip as shown is this section is about 60°.

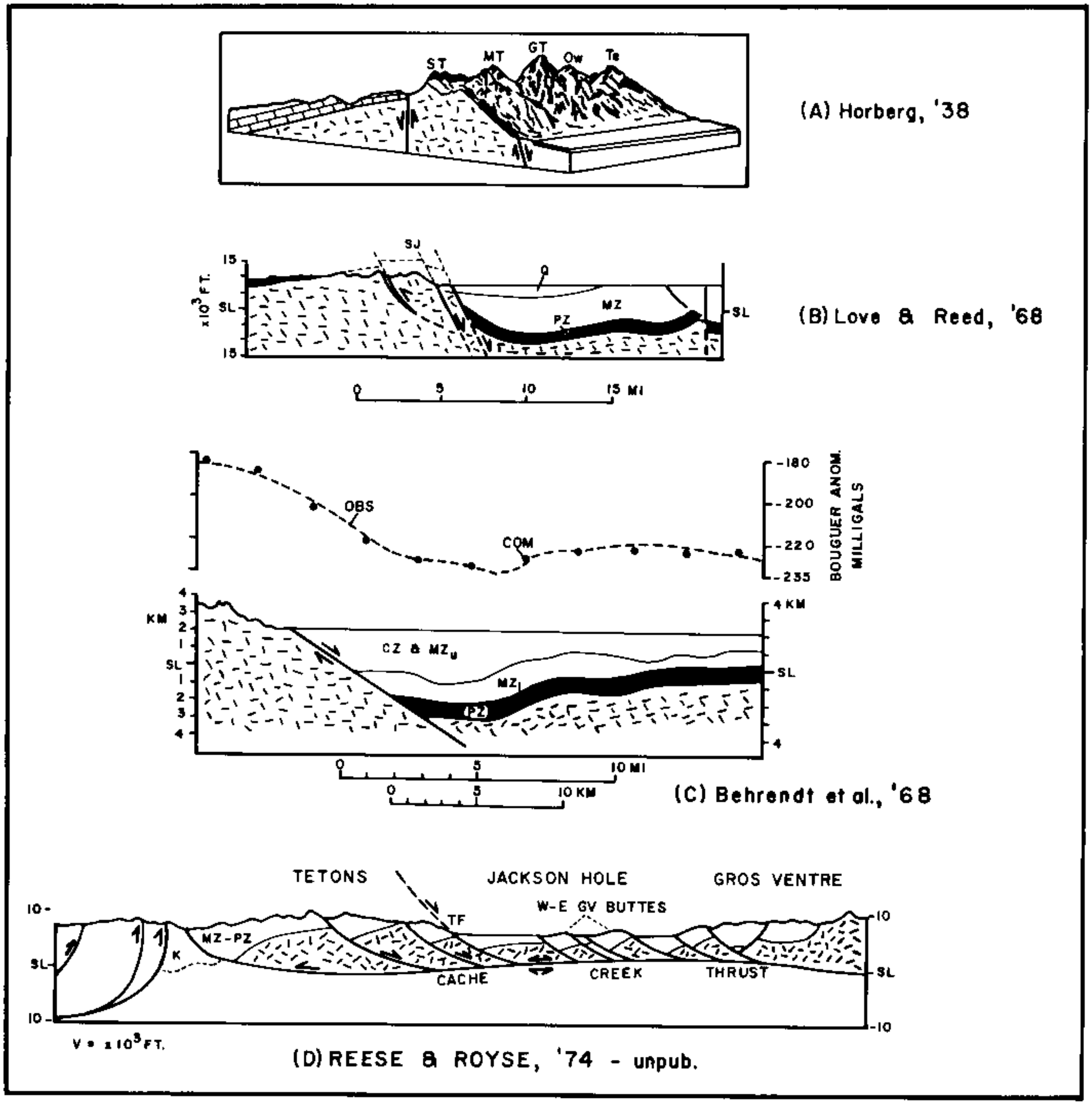

Figure 2-5: Various interpretations of the Teton Range and Teton normal fault from 1938 through 1974 (Figure 6 of Lageson, 1992). ST=South Teton; MT=Middle Teton; GT=Grand Teton; OW=Mount Owen; Te=Mt. Teewinot; SJ= Mt. St. John; TF=Teton normal fault; GV Buttes=Gros Ventre Buttes; OBS=observed gravity; COM=computed gravity. Rock units: Q=Quaternary deposits; CZ=Cenozoic rocks; K=Cretaceous rocks; MZu=Upper Mesozoic rocks; MZ=Mesozoic rocks; MZl=Lower Mesozoic rocks; MZ-PZ=Mesozoic and Paleozoic rocks, undivided; PZ=Paleozoic rocks; and Random hachures=Precambrian basement rocks.

density sediment (Figure 2-6). This further implies that the dip of the late Quaternary fault trace may not be the same as the major, basin bounding structure (Figure 2-6).

For purposes of the present study, the trace of the Teton fault defined by fault scarps on late Quaternary deposits is used as the site of the fault plane on which co-seismic rupture occurs.

2.2.2.2 Fault Dip. Available information on the dip of the Teton fault was reviewed by Byrd et al. (1994) and Byrd (1995), who concluded that the dip of the seismogenic fault lies between 45-75º. This range was derived primarily from regional information on the dip of faults associated with large normal-fault earthquakes and from limited geophysical information in the northern portion of Jackson Hole (see Byrd et al., 1994 and Byrd, 1995 for details). Most estimates compiled by Byrd et al. (1994) were within the range of 45-75º, with the notable exception of Behrendt et al. (1968) who showed a dip of 35º for the Teton fault. However, as noted in the section above, the fault of Behrendt et al. is not coincident with the late Quaternary

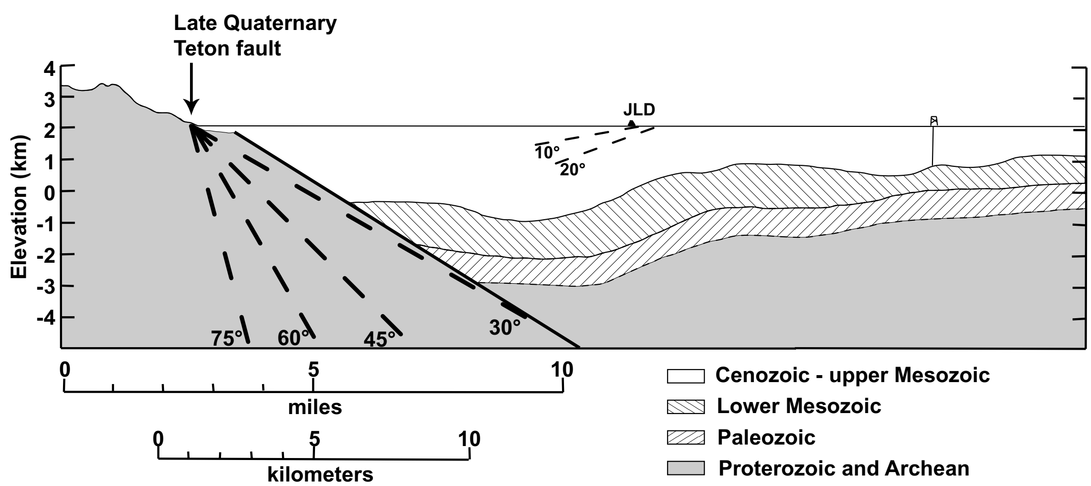

Figure 2-6: Schematic geologic cross section depicting late Quaternary Teton fault versus basin structure to east of fault. The subsurface configuration of Mesozoic and Paleozoic sediments beneath Jackson Hole is based Behrendt et al. (1968). Note that western basin boundary fault (Teton fault of Behrendt et al., 1968) dips about 35º east and is offset about 1-2 km from the trace of the late Quaternary Teton fault. Possible subsurface projections of the late Quaternary Teton fault are shown with thick dashed lines for dip ranges of 30-75º. Thin dashed lines beneath JLD (Jackson Lake Dam) show projected positions of Huckleberry Ridge Tuff, 10º, and Conant Creek Tuff, 20º, which have been rotated westward by late Cenozoic movement on the Teton fault.

fault trace and more likely reflects an older, basin-bounding structure(s) rather than indicating the dip of the late Quaternary seismogenic fault.

Along the late Quaternary fault trace, the fault exposed in the trench at Granite Creek had a dip of 75-85º based on the 2-m high exposure in the trench (Byrd, 1995). Near-surface steepening of fault planes in surficial alluvium has long been recognized and dips from the trench exposures are clearly oversteepened. The fault scarps along the Teton fault traverse several areas of significant relief which potentially could be used to estimate fault dip over elevation ranges of 50 - 300 m. However, the surface trace of the fault is very irregular, consisting of fault planes with multiple orientations, and many step-overs. This complex geometry, combined with the relative lack of detail associated with the existing compilations of fault scarps, has thus far frustrated any attempts to use the fault scarp data to generate a meaningful estimate of fault dip.

Evidence from historical normal-faulting earthquakes in the western United States, notably the 1959 Hebgen Lake and 1983 Borah Peak earthquakes, indicates that fault planes that ruptured during these earthquakes likely had dips near 45º (e.g., Smith and Arabasz, 1991). Further compilations of data from large normal-faulting earthquakes suggests that there is marked preference for dips near 45º, but with significant spread over a range of 30-60º (Thatcher and Hill, 1991; Collettini and Sibson, 2001). There appears to be little seismological evidence for fault dips of less than 30º in association with historical normal-faulting earthquakes.

The evidence from the historical earthquakes indicates that a preferred dip of about 45º, and a range of 30-60º should be considered as the likely range of dips associated with fault rupture on the late Quaternary trace of the Teton fault. The dips of buried faults within the basin, such as the fault trace defined by Behrendt et al. (1968) are probably lower than the currently active fault trace. Most models of fault basin evolution suggest that these intrabasin faults likely have dips that are less than the currently active fault due to rotation on the hangingwall block (e.g., Buck, 1993; Wernicke, 1995; Lavier et al., 1999). Thus, the 35º dip of the Teton fault as shown by Behrendt et al. (1968) is further evidence that the lower bound on the for the presently active trace of the Teton fault is probably greater than 30º.

2.2.3 Slip Rate and Along-Strike Variations in Displacement. There are four types of data that allow estimates of slip rates for the Teton fault: 1) estimated stratigraphic offsets of the pre-Cenozoic bedrock units and late Cenozoic volcanic units, 2) detailed topographic maps and profiles across fault scarps on late Quaternary deposits, 3) measured displacements from the trench across the fault scarp at Granite Creek, and 4) estimates of slip based on submerged shorelines beneath Jackson Lake. Not all of these data are directly comparable because of differences in the way these estimates are derived. Further, not all investigators have been clear in stating whether their slip rates or displacement values represent vertical estimates or displacement along a fault of unspecified dip. Despite these difficulties, the first type of data provide long-term values for large sections of the fault because outcrop data are compiled from a large region and combined into a single cross section. The scarp profile and trench data provide estimates of slip at specific locations along the fault that reflect the behavior through the last several faulting episodes at specific points along the fault. Combinations of these point data can be used to derive averaged values along the length of the fault. Estimates of slip rate derived from the submerged shorelines beneath Jackson Lake again represent a set of averaged values for a large section of the fault, but have the advantage the areal variations in the shoreline deformation can be described and related to the displacement on the fault.

A significant source of uncertainty for slip rate estimates derived from the pre-Cenozoic and late Cenozoic rock units is related to the dip of the fault and the width and number of fault traces that may comprise the fault zone. The potential for slip on multiple fault traces and effects of rotation through time greatly complicate these estimates and their reliability. Because outcrop data must be projected to the estimated fault location, even vertical displacement estimates are sensitive to the assumed fault dip and width. Thus, these estimates should be considered only as providing very loose constraints on contemporary slip rates. Byrd et al. (1994) summarized previous displacement estimates for the Teton fault, which ranged between 2 and 11 km of total slip.

Estimates of the total displacement for the central portion of the Teton fault range from about 6 km (4 mi) (Smith et al., 1993b) to about 10 km (6 mi) (Love, 1977). These values are based the estimated stratigraphic offset of Precambrian and Cambrian rock units in the central portions of Jackson Hole (Figure 2-4). The age of initial displacement on the Teton fault is not known with certainty, but appears to be near the time of deposition of the Conant Creek Tuff based on the concordancy of dip between this unit and older, underlying units in Jackson Hole (Gilbert et al., 1983; Smith et al., 1993b). Based on these relations, an age for initial movement on the Teton fault of about 5 to 6 Ma is commonly assumed, yielding long-term average slip rates of about 1-2 mm/yr (e.g. Gilbert et al., 1983; Smith et al., 1993b). Somewhat lower rates could be derived based on the Byrd et al. (1994) preferred displacement value of 2.5 - 3.5 km.

Similar long-term slip rates can be derived from the estimated offset of the Conant Creek Tuff and Huckleberry Ridge Tuff in the northern portion of Jackson Hole. Offset is estimated based on the observed westward tilt of outcrops in the area (e.g., Figure 2-6). Vertical offset of the 4-6 Ma yr old Conant Creek Tuff may be on the order of 5 km (3 mi) suggesting a long-term rate of about 1 mm/yr (Pierce and Good, 1992). Leopold and Love (2002) suggest that uplift on the Teton fault was in two phases, the most recent of which post-dated deposition of the Huckleberry Ridge Tuff. Projections of the 2-Ma yr old Huckleberry Ridge Tuff suggest vertical offset on the order of 2400 - 2800 m (Gilbert et al., 1983) and resultant slip rate estimates of 1.25 mm/yr ± 20% (Pierce and Good, 1992). The southernmost outcrops of these tuffs in Jackson Hole are located near Jackson Lake Dam, but outcrops north of the dam and east of Jackson Lake are faulted by several other subsidiary faults which also probably contribute to the observed tilts. Thus, while topographic relief on the Teton Range diminishes to the north along the west shore of Jackson Lake, presumably indicating decreasing displacement on the fault, observed tilt on outcrops of the Huckleberry Ridge Tuff does not diminish to the north (see data in Gilbert et al., 1983, Figures D-2 and D-3). However, if some displacement of the Huckleberry Ridge Tuff resulted from displacement on other subparallel traces of the Teton fault, the estimated vertical displacement derived from the tilt of Huckleberry Ridge Tuff outcrops may be considerably less.

As discussed previously, there is little data on the actual dip of the Teton fault, which Byrd (1995) estimated to be 45-75º. For this range of dips, the difference between the true slip and the vertical slip rate would be between about 10-40 per cent, with vertical slip underestimating true slip. Love and Montagne (1956) suggested that the westward tilt of alluvial surfaces in Jackson Hole south of Jenny Lake was due to movement on the Teton fault. Based on boundary element models, Byrd et al. (1994) estimated that the westward tilt interpreted in surfaces in the Love and Montagne

(1956) profiles was consistent with a minimum of 110-125 m dip-slip displacement on the Teton fault over a depth range of 0-15 km and dips of 45-75º. Based on the surface ages of 25,000 to 75,000 years used by Byrd et al. (1994) in their analyses, the minimum slip rate for the fault south of the Jenny Lake area would be 1.5 - 5 mm/yr. However, their analysis did not account for the pre-existing depositional slopes of the surfaces towards the Teton fault, which likely would reduce the slip rate estimate substantially.

Estimates of late Quaternary vertical slip on the Teton fault from scarp profiles (e.g., Bucknam and Anderson, 1979) have been made at about 17 sites along the length of the fault (Appendix A, Table A-2). These profiles provide measured estimates of the vertical component of fault slip; which must then be increased for the dip of the fault to obtain a true estimate of slip. At most sites this adjustment is probably relatively small because the near surface dip of the fault is probably 60-75º based on exposures from the trench at Granite Creek.

An additional source of uncertainty arises from the potential for a lateral component of slip on the fault. At most sites, there are insufficient geomorphic data to determine whether a lateral component of slip is present or absent. However, a some sites along the fault, particularly where the fault has a marked NE strike, it appears that significant left-lateral slip may be present (e.g., Smith et al., 1993b). At a few of these sites, detailed topographic surveys of the offset landforms permit estimates of the lateral slip component and appear to indicate that at least locally, lateral and vertical slip components may be nearly equal (Smith et al., 1993b; Byrd, 1995). At these sites, estimates based solely on the vertical offset from the scarp profiles may be as much as 40 per cent too low. However, the largest source of uncertainty in the calculated slip rate is introduced by the lack of data on the age of the deposits on which the scarp profiles are measured. At several of the sites where scarp profiles have been measured, there is a factor of 2 to 3 uncertainty in the age of the faulted deposits (Appendix A, Table A-2).

Vertical slip rates on the Teton fault are largest in the central section of the fault, and decrease towards both ends (Figure 2-7 and Appendix A, Table A-2). The overall pattern of displacement along the fault is only weakly correlated to the topographic expression of the range (Byrd, 1995), except along the northern part of the range where the topographic expression of the range mimics

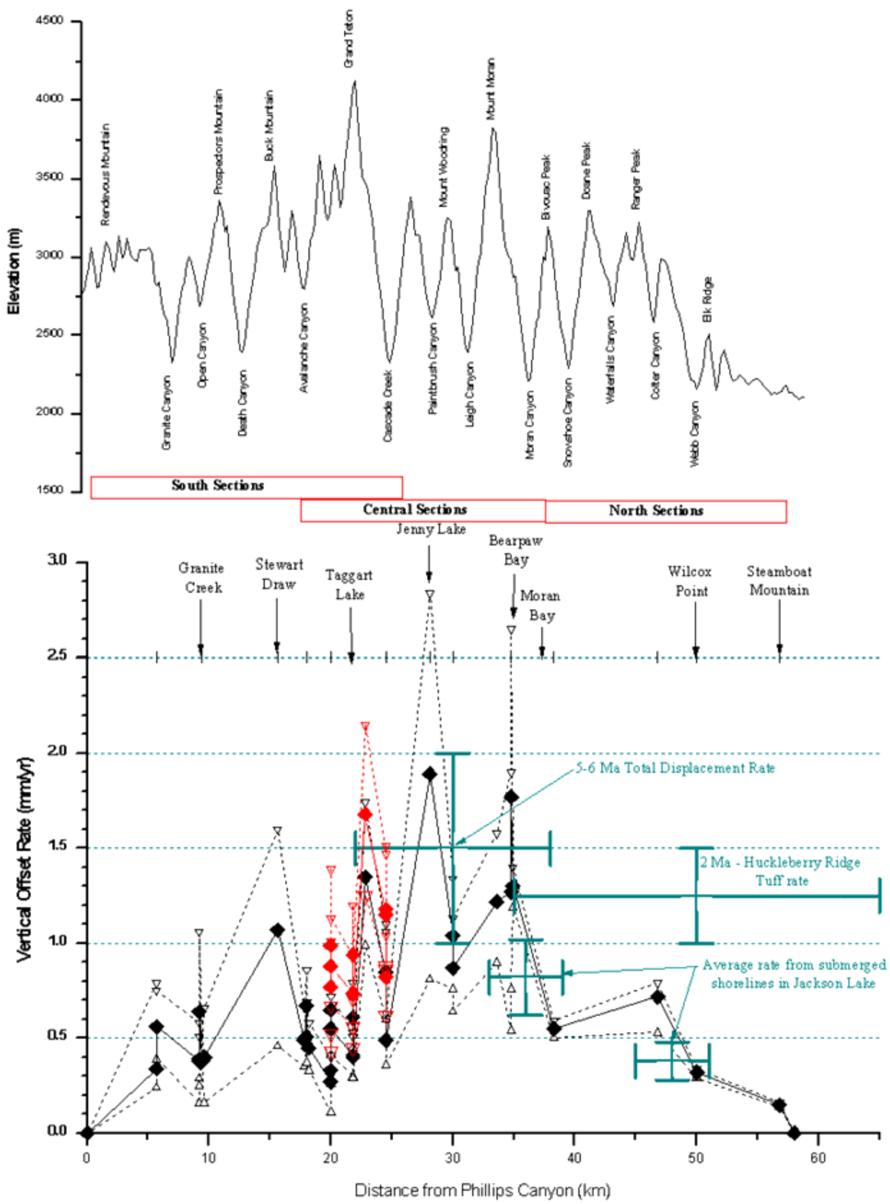

Figure 2-7: Estimated vertical slip rates along the Teton fault. Upper graph shows range profile footwall block along a line about 2-3 km west of late Quaternary fault trace. Major peaks are labeled above the profile; major canyons are labeled below the profile. Fault sections and selected geographic locations are shown between graphs; for complete data see Appendix A, Table A-2. Slip rate data are shown in lower graph: diamonds show slip rates from scarp profiles; filled symbols are mid-range values, open symbols depict uncertainty in rate, primarily due to uncertainty in age of the faulted deposits. Red symbols show effects of considering lateral component of offset on slip rate. Blue bars show rates derived from other records. Vertical extent of bars shows uncertainty in slip rate estimate. Horizontal bars depict areal extent of applicability of the rate information along the fault.

the pattern of slip along the fault. Vertical slip rates along the southern section of the fault, south of the Taggart Lake area, appear to mostly lie in the range of 0.3 - 1 mm/yr. However, along this section of the fault, there are several sites where the lateral separation appears to be nearly as large as the vertical offset (Smith et al., 1993b). In the central section of the fault, from the Jenny Lake area to Moran Bay, most vertical slip rates are in the range of 1 - 2 mm/yr, and may be as high as 2.5 - 3 mm/yr. The highest slip rate estimates are all obtained from scarp profiles along the crest of moraines constructed by Teton Range glaciers. These types of sites are potentially susceptible to secondary deformation which could enhance the size of the scarps, and have very large uncertainties in their ages as well (Appendix A, Table A-2). North of Moran Bay, vertical slip rates are again in the range of 0.3 - 0.7 mm/yr for a >10-km-long section of the fault along the west shore of Jackson Lake. Vertical displacement appears to gradually decrease over the northernmost 10 km of fault length and dies out on the east side of Steamboat Mountain.

Previous studies that characterized slip rate on the Teton fault have used basically the same data discussed above. Machette et al. (2001) placed most sections of the Teton fault in a slip rate category of 0.2-1 mm/yr. The northernmost section of the fault near Steamboat Mountain was listed as <0.2 mm/yr and the central section as 1-5 mm/yr. Wong et al. (2000) included four weighted slip rate values between 0.5-4 mm/yr. Values of 1.5 and 2 mm/yr received 70 per cent of the weight in their model.

For this study, we note that slip rates vary substantially along the length of the fault and are strongly dependent on the assumed dip of the fault. Uncertainty in the ages of the faulted late Quaternary deposits contributes substantial uncertainty, as does the need to account for observations of lateral displacements at several sites along the fault. Despite these factors, it appears clear that the maximum slip rate for the late Quaternary Teton fault occurs along the section of the fault just west and south of Jackson Lake, and is probably near 2 mm/yr, but could be as large as 5 mm/yr if the fault dip is low. Slip rates appear to taper to zero over distances of 5 to 10 km at each end of the fault (Figure 2-7).

2.2.3.1 Age(s) and Number of Faulting Events. Detailed information on the age, number, and extent of faulting events along the Teton fault is generally lacking. Limited information is available from two areas located about 25-40 km apart (Table 2-1): 1) a trench on

Table 2-1: Teton Fault - Event Data

Fault Section	Site Name	Geomorphic Setting and Type of Evidence	Age of Faulting Events (thousands of years)	Number of Faulting Events	Inferred Average Return Period (thousands of years)	Estimated Vertical Displacement per Event (m)	Data Source
North Teton* (N5? to N9?)	Snake River Delta	Snake River, Lizard and Arizona Creek fan-delta alluvium and pre-reservoir Jackson Lake shorelines. Backflooded delta deposits and beaches constructed across Snake River alluvium. Landforms from secondary deformation.	~ 2 ~4	2 subsidence* or strong ground shaking events in the past 4,000 years.	~2 since 4 ka	>0.7 from delta backflooding for MRE; earlier event uncertain.	Pierce and Good, 1992; Connor, 1998
North and/or Central Teton (N11 to C4?)	South Jackson Lake - east of Bearpaw Bay and east of Spaulding Bay	Submerged pre-reservoir Jackson Lake shorelines	all younger than 17	Ten subsidence events in the past 17,000 years	1.6 - 2.1 over past 17 ka	>1.4 from spacing of shorelines east of Bearpaw Bay; >0.8 from spacing of shorelines east of Spaulding Bay.	Pierce and Good, 1992; Connor, 1998
South Teton S-5 and S6	Granite Creek	Trench exposure of faulted post-glacial deposits.	~ 4 ~7.9	2 displacement events in the past 8,000 years	~ 4 since 8 ka	~ 2 ± 0.8 (1.3 @ 4 ka and 2.8 @ 7.9 ka)	Byrd, 1995; Byrd et al., 1994; Smith et al., 1993a,b;

* The post-earthquake position of shorelines relative to lake level is controlled by the relative subsidence of the outlet of Jackson Lake and the pattern of subsidence along the fault (See Figure 18 of Connor, 1998). Subsidence of the southern end of the lake, and/or the outlet area, resulting from a displacement event on the central section of the fault, could result in stranding or apparent "uplift" of shoreline features in the Snake River Delta area, even if no associated displacement were to occur on the northern section of the fault.

the southern section of the fault near Granite Creek (Byrd, 1995; Byrd et al., 1994; Smith et al., 1993b) and 2) from shorelines of the pre-reservoir Jackson Lake (Pierce and Good, 1992; Connor, 1998).

Results from trenching at Granite Creek indicate two surface faulting events, one about 4000 years ago and an earlier event about 7900 years ago (Byrd, 1995). These data appear to suggest intervals of nearly 4000 years between faulting events on the southernmost portion of the fault.

Adjacent to the northern end of the fault, near Bearpaw and Spaulding Bays in Jackson Lake, submerged shorelines appear to indicate 8 to 10 earthquakes since deglaciation about 17,000-18,000 years ago (K. Pierce, personal comm., 2002). This implies average intervals between earthquakes of less than 2000 years for at least the central portion of the fault adjacent to Bearpaw and Spaulding Bays. The apparent submergence, based on the spacing of the submerged shorelines, is relatively uniform over the entire record (Figure 2-8), although no specific ages have been obtained for any of these shorelines. Data from shorelines near the Snake River delta at the north end of Jackson Lake indicate a submergence event on the delta about 2000 years ago, and a strong ground shaking event about 4000 years ago (Pierce and Good, 1992). These are presumed to be related to faulting events on the northern section of the fault, although the extent of fault rupture associated with these events is not constrained and could involve rupture on the central section of the fault as well. Shoreline submergence results from changes in lake levels that are a complex product of subsidence at the shoreline site and subsidence and/or base level changes at the natural outlet of Jackson Lake (Pierce and Good, 1992; Conner, 1998). Thus, the shoreline data are difficult to relate to specific faulting scenarios along the Teton fault.

2.2.4 Segmentation. The existing data are not sufficient to determine whether the Teton fault is segmented (Machette et al., 2001). As summarized above, there is only limited data available on the age of individual faulting events, mostly from sites near the ends of the fault (Table 2-1). The fault geometry lends itself to subdividing into fault sections, which some investigators have also used as a basis for segmentation. For example, Smith et al. (1993b) suggested that the fault consisted of 2 or 3 segments based primarily on strike changes and geophysical data. However, Ostenaa and Gilbert (1988) noted that the fault geometry was consistent with rupture along entire fault length.

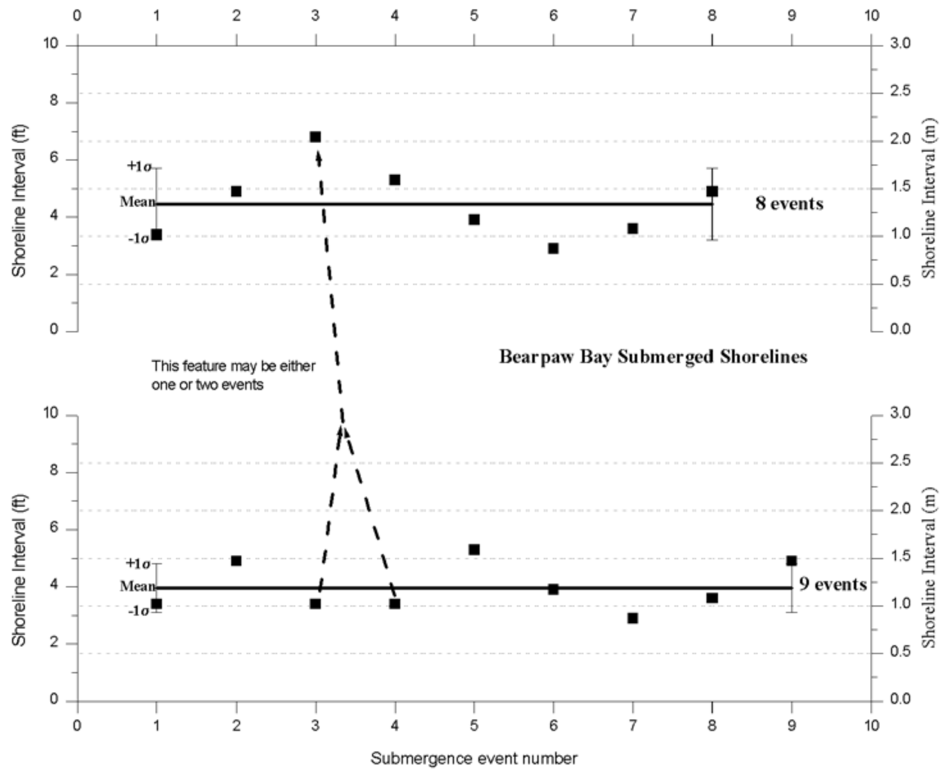

Figure 2-8: Shoreline intervals for Bearpaw Bay shorelines. Solid bar shows mean and 1s variation for event shoreline interval based on either 8 (upper panel) or 9 (lower panel) submergence events. Data from K. Pierce (personal communication, 2002).

2.3 Potential Fault Rupture Models

Based on the existing geologic data, three general groups of potential rupture models are proposed for the Teton fault. Of these models the first is considered somewhat more plausible, primarily because of its simplicity, while the second and third models are considered less plausible. One of the strongest constraints on faulting behavior comes from the submerged shoreline data from Jackson Lake. This data appears to imply that the displacements for each of the faulting events on this part of the fault are relatively similar, and provide a data point for the approximate average frequency of submergence events during the past ~17,000 years. The extent to which the models honor these data is the primary discriminant amongst the models.

General fault geometry is described in the previous section. The only difference in fault geometry for each of the models is in the length and amount of displacement along strike. Potential linkage of the Teton fault with the Beula-Herring Lake faults, as proposed by Wong et al. (2000), is not considered in this analyses because of the apparent lack of evidence for surface rupture on these faults (Ostenaa et al., 1993), the much smaller long-term slip rates on these faults compared to the northern section of the Teton fault, and the 30+ km distance for the closest approach of these faults to Jackson Lake Dam. Slip rates on the northern section of the Teton fault appear to be mostly in the range of 0.3 - 0.7 mm/yr and decrease to the north (Figure 2-7 and Appendix A, Table A-2). They are nearly an order of magnitude greater than long-term slip rates for the Buela - Herring Lake faults (see data tabulation in Wong et al., 2000).

2.3.1 Unsegmented, with Variable Displacement Along Strike. This type of fault rupture model appears to provide the most simple reconciliation of the limited data for individual faulting events along the Teton fault. In this model rupture extends over nearly the entire length of fault, up to 58 km for the largest events and ~40-45 km for slightly smaller events. The displacement pattern varies along strike as shown by variations in slip rate (e.g., Figure 2-7). Displacement near Moran Bay is ~1.5 m as indicated by average spacing of submerged shorelines in Jackson Lake. Maximum displacement is ~4.5 m on sections of the fault near Bearpaw Bay and Jenny Lake. For some events, rupture does not extend fully to the south end of the fault which could account for differences in the age of the most recent event at the Granite Creek trench site versus the age of apparent faulting events from submerged shorelines on the Snake River delta in Jackson Lake. This model would appear to imply nucleation of most ruptures on the central and northern sections of the fault. On average, for this model there is one faulting event about every 1700-2000 years based on the number of submerged shorelines in Jackson Lake (i.e., there have been 8-10 large surface faulting earthquakes in the past 17,000-18,000 years on the Teton fault). Thus, about half of the faulting events would not include full rupture of the southern 10 - 15 km of the fault (fault sections S3-S10 on Figure 2-3), including the Granite Creek trench site (Byrd et al., 1994; Byrd, 1995). Earthquake magnitudes for these events would likely be somewhat smaller than for events that involve the entire fault length.

2.3.2 Two Independent Fault Segments with Overlapping Rupture. In the second fault rupture model, the northern and southern sections of the fault behave independently, but have overlapping rupture on the central section of the fault. Individual earthquake magnitudes would be somewhat smaller in this model, but the total number of large earthquakes on the fault over a given time interval might be larger than in the first model. A northern fault segment would rupture between the area of Taggart Lake and Steamboat Mountain, with displacement of ~1.5 - 2 m along much of the 35-40 km length. Maximum displacement would be in the area between Jenny Lake and Bearpaw Bay. A southern fault segment would rupture between Phillips Canyon and Bearpaw Bay. Displacement would be ~2 m along much of the segment with maximum displacements in the Taggart Lake to Jenny Lake area. Total rupture length would be ~35 km. On average, this model implies one faulting event every 2000 years on the northern segment, and one faulting event every 4000 years on the southern segment. Thus, over a time of 17,000-18,000 years, possibly 12-14 large surface-faulting earthquakes might originate on the Teton fault.

2.3.3 Three Independent Fault Segments. This model implies that individual fault ruptures on the Teton fault would be limited in length to about 20-25 km, and hence typical magnitudes would be somewhat smaller than in either of the previous two models, but significantly more large earthquakes would need occur. The northern, central, and southern sections of the fault each rupture as independent fault segments with negligible overlap. Rupture on the northern segment would extend between Steamboat Mountain and Moran Bay, a distance of ~20 km. Maximum displacement would be ~1.5 - 2 m along the western shore of Jackson Lake. Rupture on the central segment of the fault would extend between Taggart Lake and Moran Bay, a distance of ~25 km. Displacement would either be ~1.5 - 2 m along much of the length of the fault, or 2-3 times that if events are somewhat less frequent. Rupture on the southern fault segment would extend between Phillips Canyon and Taggart Lake, a distance of about 22 km. Displacement would be ~2 m along much of the fault segment. On average, there is one faulting event every 2000 years on the northern fault segment, one faulting event every 1700 years on the central segment of the fault, and one faulting event every 4000 years on the southern segment of the fault. This would imply that over a period of 17,000-18,000 years, the Teton fault would be the potential site of 20-25 large surface rupturing earthquakes.

2.3.4 Implications for Ground Motion Models. The general lack of specific paleoseismic event data for the Teton fault implies that potential ground motion models based on specific fault slip geometries need to consider a broad range of scenarios. At present there is insufficient data to reliably discriminate amongst these potential scenarios. The existing geologic data appear to be permissive of paleoseismic events associated with surface rupture lengths of ~20 to ~60 km and individual slip events of 1.5 - > 5 m. If most paleoseismic events have somewhat shorter rupture lengths and smaller individual slip, the average frequency of events will be much shorter and earthquake magnitudes will be somewhat smaller. As outlined in the Sections 2.3.1 to 2.3.3 and summarized in Table 2-2, the average intervals between large surface-rupture events on the Teton fault could be as low as several hundred years or as long as a few thousand. What appears to be the most simple model of fault rupture on the Teton fault, i.e, an unsegmented model, suggests that large events involve most of the fault area with average return intervals of about 1700 to 2000 years. If the fault is segmented to any extent, the average return interval for large events decrease significantly. Because Jackson Lake Dam is located nearly astride the likely boundary of the northern and central sections of the fault, rate and event data for these sections of the fault appear to be most significant to the ground motion evaluations for the damsite. For use in simplified probabilistic analyses, the unsegmented scenario could be weighted 0.5, the two segment scenario weighted 0.3, and the three segment scenario 0.2, leading to a mean average return interval of about 1180 years.

Table 2-2: Teton Fault Rupture Scenario Summary

Fault rupture scenario	Number of fault rupture segments	Estimated number of paleoearthquakes in past 17-18 ka.	Average earthquake return interval (ka)	Typical rupture length (km)	Typical paleoearthquake magnitude* (M_w)
Unsegmented, with variable displacement along strike	1	8 - 10	~1850	45 - 60	7.1
Two independent fault segments with overlapping rupture	2	12 - 14	~1350	35 - 40	6.9
Three independent fault segments	3	20 - 25	~800	20 - 25	6.7

*Typical magnitude for 45° fault dip and 16 km rupture depth from fault-area relationships of Wells and Coppersmith (1994).